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LOCATION AND STRENGTHS OF CORRECTION DIPOLES IN THE LOW-β INSERTION

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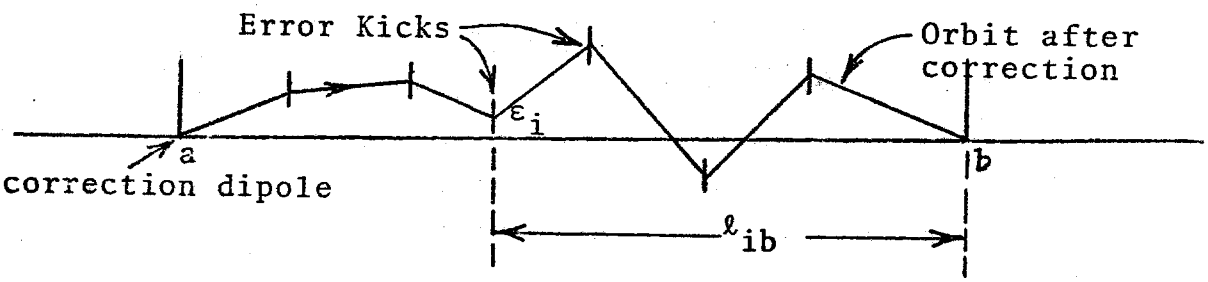
There seems to be a preference for separate correction dipoles instead of correction dipole coils installed in the aperture of the low-β quadrupoles. We give here the minimal requirements for the number, the locations and the strengths of these correction dipoles.

Normally, correction dipoles each capable of maximum strength $B\ell$ = 170kG in. = 4.3kGm are placed at locations A48, A49, B11 and B12. We shall show that in the low-β insertion at BO, in addition to these we should add two more dipoles either just inboard of QI4 and -QI4 (locations denoted as A50 and B10) or just outboard of QI4 and -QI4 (locations denoted as A50' and B10'). The correction dipoles are adjusted to make the orbit distortion zero at the dipoles as shown in the following diagram



All orbit deflections are approximated as local kicks. The error kick ε_i produced by a quadrupole with alignment error δx_i is

$$\varepsilon_i = (B'\ell)_i \; \delta x_i / B\rho \tag{1}$$

and the orbit distortion at b produced by ε_i is $\varepsilon_i \ell_{ib}$ where

$$\ell_{ib} = \sqrt{\beta_i \beta_b} \sin \phi_{ib} = \text{12 element of transfer matrix from i to b.} \tag{2}$$

If δx_i are random the expectation value of the orbit distortion at b produced by all ε_i is

$$\Delta x_b = \sqrt{\sum_i (\varepsilon_i \ell_{ib})^2} \tag{3}$$

The correction dipole at a should be so adjusted as to cancell Δx_b, namely

$$\varepsilon_a \ell_{ab} = \varepsilon_a \sqrt{\beta_a \beta_b} \sin \phi_{ab} = -\Delta x_b \tag{4}$$

ε_a then gives the strength of a required for the assumed values of δx_i. With this adjustment the expectation value of the orbit distortion at a location j in between a and b is then given by

$$\Delta x_j = \varepsilon_a \ell_{aj} - \sqrt{\sum_{i<j} (\varepsilon_i \ell_{ij})^2} \tag{5}$$

The parameters for D. Johnson's Type E insertion at $\beta^* = 0.808$m and $B\rho = 33388$kGm (1 TeV) are given below. Since the insertion is antisymmetric, studying the orbit in one plane (x-plane) alone is adequate.

Location	$\phi_x/2\pi$	β_x(m)	$B'\ell$(kGm)
A49	5.95875	866.22	
Q2	5.95937	780.08	-1920
QI2	5.96036	700.48	4598
QI3	5.96221	311.65	-3552
QI3	5.96587	142.55	-3552
A50'	5.96868	116.02	
QI4	5.97221	95.31	3655
A50	5.97713	69.73	
BO	6.20837	0.808	
B10	6.43960	66.11	
-QI4	6.44414	140.85	-3655
B10'	6.44697	242.26	
-QI3	6.44803	365.98	3552
-QI3	6.44963	397.85	3552
-QI2	6.45278	211.60	-4598
-Q2	6.45763	135.14	1920
B11	6.46238	96.17	

For these parameters the performances of the various arrangements are the following.

A. Correction dipoles only at A49 and B11

Assumming alignment errors δx_i = 1mm and random for all the quadrupoles we get

Expectation value of orbit distortion at B11 due to alignment errors = 3.2mm

Required strength of dipole at A49 to give zero distortion at B11, $B\ell$ = 16.3kGm

Expection valve of orbit distortion at BO after correction = 8.7mm

With this arrangement we see that

1. Correction dipole strength required is to large.
2. Even after correction the orbit distortion at BO is too large.

B. Correction dipoles at A49, A50, B10, and B11

Again for δx_i = 1mm and random we get

Required strength of A49 dipole to give zero distortion at A50, $B\ell$ = 4.6kGm

Required strength of B10 dipole to give zero distortion at B11, $B\ell$ = 9.1kGm

Orbit distortion at BO after correction = 0

With this arrangement and standard correction dipoles ($B\ell$ = 4.3kGm) we can correct for random misalignments of $\delta x_i \sim 1/2$ mm. The correction of orbit distortion at BO is perfect.

C. Correction dipoles at A49, A50', B10', B11

For δx_i = 1mm and random we get

Required strength of A49 dipole to give zero distortion at A50', $B\ell$ = 4.1kGm

Required strength of A50' dipole to give zero distortion at B10', $B\ell$ = 3.9kGm

Required strength of B10' dipole to give zero distortion at B11, $B\ell$ = 6.2kGm

Expectation value of orbit distortion at BO after correction = 0.17mm

With this arrangement and standard correction dipoles ($B\ell$ = 4.3kGm) we can correct for random misalignment of $\delta x_i \sim 2/3$mm. The expectation value of orbit distortion at BO after correction is acceptable.

The conclusions are the following.

1. In order to be able to control the orbit distortion at BO one must use arrangements B or C.
2. If only standard correction dipoles with $B\ell$ = 170kG in. are used one must ensure that the quadrupoles are aligned to better than $\sim$1/2mm.